

# Characterization of Carbon in Coal Fly Ash

Indrek Külaots, Yu-Ming Gao, Robert H. Hurt\* and Eric M. Suuberg<sup>°</sup>

Division of Engineering  
Brown University  
Providence, RI 02912

\* Tel. (401) 863-2685, e-mail: Robert\_Hurt@brown.edu

<sup>°</sup> Tel. (401) 863-1420, e-mail: Eric\_Suuberg@brown.edu

## Summary

Previously, it was determined that the suitability of a fly ash as a pozzolanic additive to concrete depends upon several factors related to its carbon content. While historically, suitability has been determined by loss-on-ignition (LOI, a measure of carbon mass), it is the carbon's porous surface area which is more important, because this determines the capacity of the carbon to adsorb air entrainment admixtures (AEAs) [1,2]. This adsorption is undesirable, as it degrades the freeze-thaw resistance of the concrete because air bubble content is lowered. Most fly ash carbon samples have surface areas much larger than would be expected from the external geometric area of the particles. This is because the carbon particles have a large amount of porosity including micropores ( $<20\text{\AA}$ ), mesopores ( $20\text{\AA}$ - $500\text{\AA}$ ) and macropores ( $>500\text{\AA}$ ), according to the IUPAC classification.

We have previously reported that the undesired adsorption is enhanced when there exist large feeder pores and when the carbon surface is relatively non-polar[3]. Previous work had focused on class F ashes, but recently, some class C ashes have come to light which also are problematic. The differences between class C and class F ashes have not previously been considered in terms of these properties. The objective of this research was to investigate the nature of the fly ash carbon, including both the nature of its porosity and polarity, and to see how these factors both influence the adsorption of AEA's.

It appears that the porosity in carbons contained in class C ashes differs from that in class F ashes in two important characteristics. First, the carbons in class C ashes generally contain significantly more microporosity, as revealed by standard nitrogen isotherm data, and the BET surface areas derived therefrom. It is typical for class C carbons to have a surface area in the range of 300 to 400  $\text{m}^2/\text{g}$ , whereas the carbons from class F ashes have surface areas which are typically in the range from about 30 to 70  $\text{m}^2/\text{g}$ . Some unusually bad class F ashes have carbon surface areas which approach those in class C ashes. It is useful to note that the total surface

areas of the whole ashes may not immediately suggest this significant difference, because the carbon content of the class C ashes is often much lower than the carbon content of class F ashes.

A second difference in the porosities observed in the carbons from class C and class F ashes has to do with the total amount of porosity per mass of carbon. The carbons from class F ashes tend to be somewhat less porous than the carbons from class C ashes. This difference exists on the smallest scale of porosity, the micropores, already discussed above. The differences also exist in the larger scale porosities, the meso- and macro-pores. Preliminary results indicate that the size distributions of the larger-scale porosity might actually be similar, but that there is merely much less total porosity in the class C ashes.

Again, it has been previously hypothesized that the ability of a particular fly ash to adsorb AEAs, therefore determining its suitability for pozzolanic applications, depends upon three main factors [3] - the total surface area presented by the carbon in the ash (the inorganic fraction of the ash contributes very little to adsorption), the accessibility of the surface area in the carbon and the nature of the carbon surface, specifically, its polarity, which is influenced by the degree of carbon surface oxidation. A less polar surface presents a more attractive surface for AEA adsorption. There is a complicated interplay between all three factors. The carbons from class C ashes (generally associated with burning lower rank coals) should be more problematic than carbons from class F ashes (generally associated with burning bituminous coals), on the basis of the first two factors. The carbons from class C ashes have higher surface area and greater porosity. One reason that they are not more often problematic in practice is that the LOI values in class C ashes are quite low, and there is simply not enough carbon present to cause a problem. On the other hand, the comparison can explain why there have been numerous reports of problematic class C fly ashes, even when their LOI values are in the 1 to 2% range. On the other hand, there do appear to be some carbons from class C ashes that have high surface areas and moderately high porosities, and yet, are not prone to high relative AEA adsorption capacities. This might be partly attributable to the influence of surface polarity, and work on this question continues. Recent efforts at treating fly ashes in order to increase carbon polarity have been remarkably successful at improving their suitability for pozzolanic applications, at least as indicated by foam index testing. The treatments have been equally effective for both class C and class F ashes.

### **Acknowledgment**

The financial support of the US Department of Energy (grant DE-FG22-96PC96213) and the Electric Power Research Institute (Dr. Arun Mehta, program manager) are gratefully acknowledged.

## References

1. Gao, Y.-M., Shim, H.-S., Hurt, R.H., Suuberg, E.M., Yang, N.Y.C., "Effects of Carbon on Air Entrainment in Fly Ash Concrete: The Role of Soot and Carbon Black", *Energy and Fuels*, **1997**, *11*, 457.
2. Freeman, E., Gao, Y.-M., Hurt, R.H., Suuberg, E.M., "Interactions of Carbon-Containing Fly Ash with Commercial Air Entraining Admixtures for Concrete", *Fuel*, 1997, *76*, 761.
3. Külaots, I., Gao, Y.M., Hurt, R.H., Suuberg, E.M. "The Role of Polar Surface Area and Mesoporosity in Adsorption of Organics by Fly Ash Carbon", *ACS Div. Fuel Chem. Prepr.*, **1998**, *43*, 980.